3D Data Management (Overview Report)

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Preamble

- It is obvious, that the amount and use of three-dimensional data has rapidly increased in the last few years.
- The major technology and business drivers for 3D *(Boss and Streilein, 2014)*:
    1. There is a necessity for 3D data, where 2D data is not sufficient to describe our world.
    2. Managing 3D data in enterprise workflows with improved performance and scalability of existing workflows. Traditional file handling moves to database management.
    3. Massive new sensor hardware capabilities, LIDAR with masses of point clouds and automated photogrammetric workflows and processes.
    4. 3D visualisation has now come into mainstream, but 3D analysis not.

Preamble

- For cadastral organizations, who traditionally describe their cadastral data in two dimensions, entering the third dimension is difficult mainly due to the facts that *(Boss and Streilein, 2014)*:
  - one has to migrate from simple data structures to complex data structures,
  - 3D modelling is much more heterogeneous and complex compared to 2D modelling,
  - converting 2D data to 3D data on an operational level,
  - user-friendly tools for 3D analysis are still missing.

Scope of the Overview Report

- The overview report has explored 3D data management from multiple perspective.
- The focus of the data management issue in this paper has not been restricted to 3D Cadastre, but rather to a broader 3D GIS to ensure that all capabilities and issues that exist in different related fields will assist and affect in the data management of 3D Cadastral data.

Structure of the overview report

1. Introduction
2. Functional needs (requirements) for 3D cadastre data management (including 4D time)
3. Current DBMS 3D capabilities
4. Analysis of a gap
5. Conclusion

Functional needs

- In functional requirements for 3D cadastral data management, the categorisation of 3D parcels at an increasing level of complexity is discussed.
- This lead to a discussion on options for storing 3D cadastral data in an existing 2D cadastral database that traditionally exists in current jurisdictions.
- The issues related to adding the time dimension in a 4D cadastre from a database point of view was discussed.
- A discussion of 3D geometric models based on current research on standards, solid geometry and LADM schema was done, which in turn led to 3D topological models.

Current DBMS 3D capabilities

- The current DBMS 3D capabilities, current software and methods of storing 3D data were discussed which led to a discussion on recent developments of spatial databases and the physical capacity of existing hardware to cope with the large volume of 3D data.
- Oracle Spatial and PostGIS were analyzed in more detail.

Analysis of a gap

- The analysis of a gap between what is available and what is needed was based on:
  - 3D geometry and topology,
  - validation,
  - standards and ontology,
  - data and hardware,
  - 3D data transfer,
  - and implementation of a 3D LADM prototype.

3D Parcels

- What are acceptable (valid) 3D cadastral object representations and how to create their 3D geometries (even the non-2-manifold geometries) are still challenges.
- The non-manifold 3D representations (self-touching in edge or node) are not well supported by current GIS, CAD, and DBMS software or by generic ISO standards such as ISO 19107 *(Van Oosterom, 2013)*.
- How to create and maintain valid 3D parcels is still a challenge in practice *(Ying et al, 2015)*.

3D Parcels

- At least three aspects should be clearly developed in order to manage the 3D parcels correctly *(Ying et al, 2015)*:
    1. precise geometric models that describe the shapes and geographic locations of various 3D parcels, based on the flat faces;
    2. volumetric or solid models that indicate all its boundary faces with orientation to present the corresponding 3D parcel objects;
    3. the topological relationships that encode all the information about the adjacencies among 3D parcels shared common faces/edges to keep the consistency of the objects' geometries and support spatial query and management.

3D topology

- A full topological model for the 3D cadastre is suitable for the following reasons *(Ying et al, 2015)*:
    1. to utilize the surveying boundaries to generate the 3D cadastral objects;
    2. to represent the 3D volumetric objects with high quality, and consistent topology without intersection; and
    3. for the rapid topological queries necessary for real-time user interaction and management.

Validation of 3D solids

- For the validation of 3D buildings, the semantics information can be used *(Ledoux, 2014)*.
- Furthermore, the automatic repair of invalid solids could be considered.

Interrelation CityGML – LADM ADE

- The implementation of ISO 19152-conformant features in a CityGML ADE is only one of the possible approaches to combine the capabilities of CityGML and LADM *(Rönsdorf et al, 2014)*.
- A different approach would be to create an explicit overlap between the two standards and embed LADM concepts in CityGML and vice versa *(Rönsdorf et al, 2014)*.
- The semantic representation for land administration within CityGML is included in the list of work packages that define the scope of next version of CityGML (*Góźdź et al, 2014*).

BIM

- BIMS are a good source of 3D cadastral data and has already been used by many jurisdictions.
- The link between the various geometrical and semantic aspects of BIM vs other data sources can cause differences and issues when data are to be integrated.
- ISO/AWI 19166 Geographic information -- BIM to GIS conceptual mapping (B2GM)

Point Clouds and TINs

- At least two closely related level of standardization must be considered *(Van Oosterom et al, 2015)* :
  a. Database Structure Query Language (SQL) extension for point clouds, and
  b. Web Point Cloud Services (WPCS) for progressive transfer based on multi-scale or vario-scale LoD.
- The point cloud and TIN related data structures available in SDBMSs should be extended to enable storage of additional non-spatial attributes *(Janečka and Kára, 2012)*.

Compression and transfer of spatial data

- 3D models generally result in large data sets, which require special techniques for rapid visualisation and navigation.
- As the speed of geodata collection is still increasing, the need for the effective geodata compression will be essential, for example to deliver the data to the final user/application via internet *(Janečka and Váša, 2016)*.

3D LADM prototype

- Cadastral systems meet serious complications with providing information about the legal status of properties in case of 3D complex situations
- In the last few years several prototypes of 3D LADM based country profiles have been developed (Poland, Malaysia, Israel, Turkey,…)

Open data and smart cities initiatives

- One of the new areas is the creation of the 2D and 3D registries in the context of open data and smart cities initiatives that are aimed at providing a platform for city data.
- The inclusion of geospatial and building data in this context is paramount (*highlighted e.g. by the British Standard Institutions City Data Survey Report*).

Conclusion

- 3D data management capability and technology exist, however these have not been transferrable to 3D cadastre.
- The problem is, established cadastre are traditionally 2D and the nature of the cadastral data does not easily extend itself to 3D modelling.
- While 3D GIS data may be easy to extrude to create a 3D visualisation, because 3D cadastre deals with absolute ownership of 3D spaces it becomes much more complex to convert a 2D database to a 3D operational data structure.

Conclusion

- The extrusion of 2D to 3D might still be a feasible solution for a cadastre if the purpose is just visualisation, however, if the purpose is to define ownership of defined space, information about the adjoining 3D spaces, checks to determine encroachment or slivers among the spaces, then a simple extrude does not fulfil the requirements.

Future direction

- Important directions for 3D SDBMS research include the integration of 2D and 3D data models and development of dimension-independent topological and geometric models.
- These data models should be uniformly usable for both 2D and 3D worlds.
- The challenges for future research include spatial data integration, new user interfaces for SDBMS (augmented reality), development of 3D/4D geo-information systems, and geo-sensor databases.

Future direction

- A database should be able to efficiently manage un-processed raw data such a large point clouds.
- Persistent storage of raw data will support the 3D modelling process, allowing re-use of source data while constructing a 3D model *(Breunig and Zlatanova, 2011)*.

Thank you for your attention!

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